Meeting the Unique Challenges of Pavements Engineering in the Urban Context, City of Calgary

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ABSTRACT

Pavements engineering for urban applications is unique and differs in many aspects to that of rural or highway applications. This represents a challenge for major municipal agencies in maintaining the desired level of serviceability of pavements in the most cost effective manner. Over the past decade, the City of Calgary has initiated a number of processes and technologies to address the unique demands of urban pavements.
Transit bus traffic, not typically encountered in rural applications, represents the most significant loading to which an urban major roadway is subjected in many cases. The loading associated with articulating transit buses can be ten times or more than that of a standard single unit truck. In addition, the stresses of this type of loading can significantly impact surfacing materials and the resulting performance, and the potential move to electric transit bus types will further increase the effects of these vehicle types. Instability rutting of flexible pavements, and in particular intersection rutting is another aspect of pavement performance that is relatively unique to the urban context. This represents not only a pavement distress causing a reduction in service life, but a significant safety concern. The use of reclaimed materials is generally more of a consideration in the urban context, due to the significant ongoing supply of materials such as Reclaimed Asphalt Pavement (RAP) and Reclaimed Asphalt Shingles (RAS). Although, jurisdictions such as the City of Calgary have been leaders in utilizing these types of materials, there needs to be a compromise between increased use of reclaimed materials and pavement performance. Other aspects of urban pavements represent restrictions that must be accommodated in the design and construction processes. Underground utilities and the need to maintain pavement surface elevations result in impacts on potential subsurface activity, while decreasing the number of options available to rehabilitate and maintain roadways. Traffic accommodation and maintaining business access are also challenges that must be considered during the design and construction of urban pavement rehabilitation and reconstruction.
The City of Calgary has, over the past number of years, developed processes and considered newer technologies in addressing the unique challenges of urban pavement performance. This paper will discuss many of these initiatives including enhanced specification development, use of newer technologies to minimize intrusive testing and the implementation of alternate materials for roadway construction (such as Stone Matrix Asphalt (SMA) Polymer Modified Asphalt Binders (PMA) and concrete pads at bus stops). The paper will also discuss the City's experience with the use of RAP and RAS, and some of the limitations that have been experienced.

INTRODUCTION

Pavements engineering for urban applications is unique and differs in many aspects to that of rural or highway applications. This represents a challenge for major municipal agencies in maintaining the desired level of serviceability of pavements in the most cost effective manner. Over the past decade, the City of Calgary (the City) has initiated a number of processes and technologies to address the unique demands of urban pavements.

This paper discusses in detail the some of the challenges that the City faces and some of the initiatives that have been developed to address those challenges.

BACKGROUND

Transit bus traffic, not typically encountered in rural applications, represents the most significant loading to which an urban major roadway is subjected in many cases. In addition, the stresses of this type of loading can significantly impact surfacing materials and the resulting performance, and the potential move to electric transit bus types will further increase the effects of these vehicle types.

Instability rutting of flexible pavements, and in particular intersection rutting is another aspect of pavement performance that is relatively unique to the urban context. This represents not only a pavement distress causing a reduction in service life, but a significant safety concern.

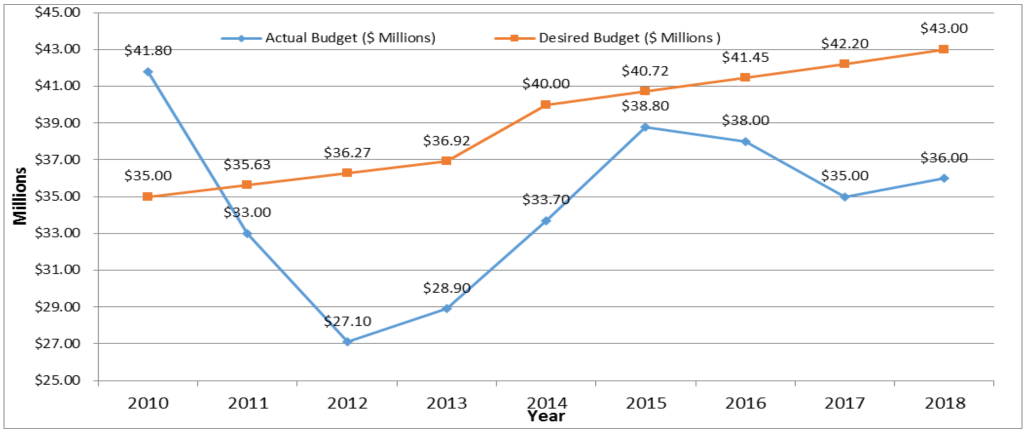
The use of reclaimed materials is generally more of a consideration in the urban context, due to the significant ongoing supply of materials such as Reclaimed Asphalt Pavement (RAP) and Reclaimed Asphalt Shingles (RAS). Although, jurisdictions such as the City of Calgary have been leaders in utilizing these types of materials, there needs to be a compromise between increased use of reclaimed materials and pavement performance.

Other aspects of urban pavements represent restrictions that must be accommodated in the design and construction processes. These include underground utilities, traffic accommodation and maintain business accesses. These are challenges that must be considered during the design and construction of urban pavement rehabilitation and reconstruction.

CITY OF CALGARY PAVEMENT NETWORK AND TYPICAL ANNUAL BUDGETS

The City of Calgary has a road network surface of approximately 15,000 Ln-km and 5500 km of sidewalk with an estimated asset value of $ 12 Billion and 5 Billion respectively. The network is composed of four functional classes: Arterial (26%), Collector (21%), Industrial (3%) and local roads (50%).

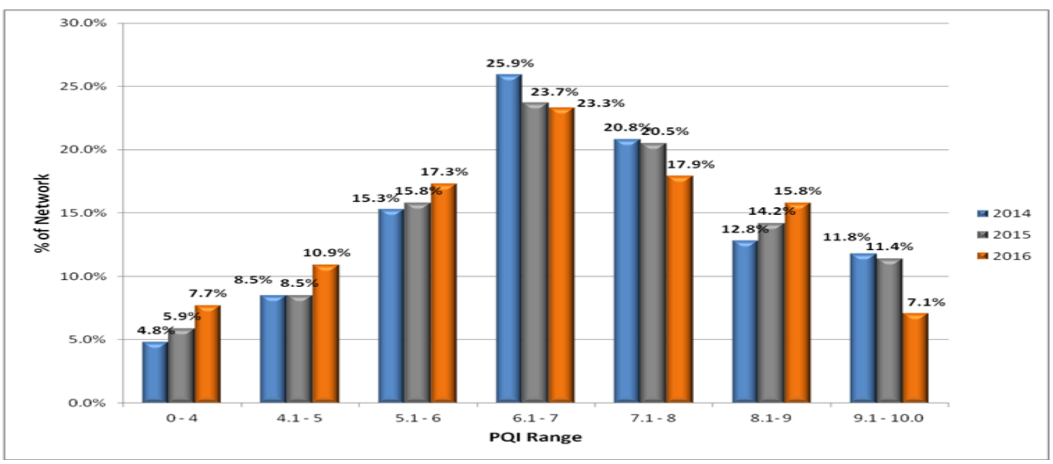
Figure 1 Pavement Life Cycle Rehabilitation Budget



The network performance is evaluated with a pavement data collection program to develop cost-effective solutions according to the needs found for actual and future interventions and budgets. Surface data is collected every second year for arterials and collectors with heavier traffic.

Pavement Quality Index (PQI) gives a general picture of the network and help to prioritise and predicting how fast the intervention has to be done and to manage the funds to be invested.

Figure 2 Pavement Network Performance by PQI



For residential roads, manual data is collected every six year. This data is converted into Pavement Quality Index (PQI) that is an overall index adopted by the City as the indicator that measures and evaluates the network condition.

Table 1 Pavement Performance by Roadway Classification

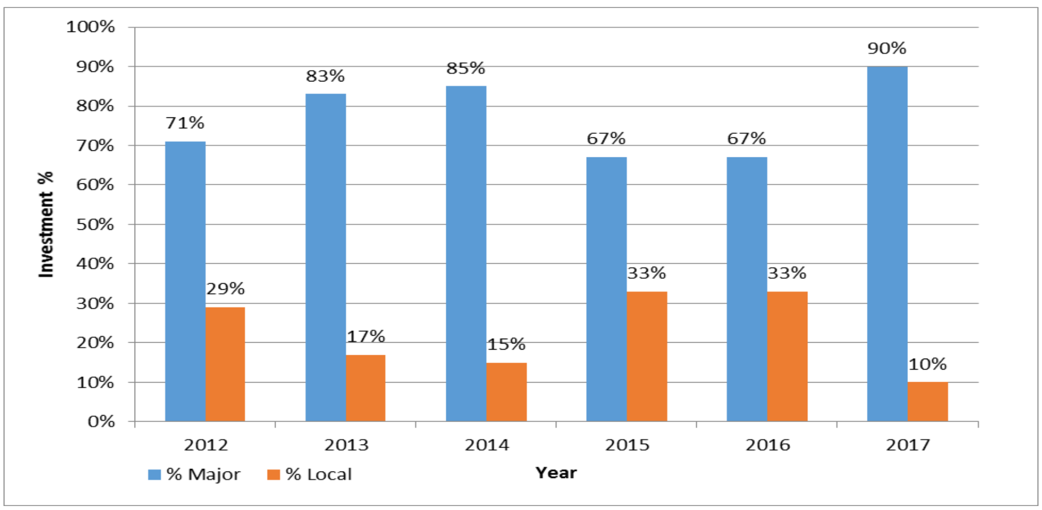
Functional Class	Ln-km	Trigger PQI	2015 Avg. PQI	2016 Avg. PQI
Arterial	3,800	6.0	6.2	6.3
Collector	3,200	5.0	5.9	5.6
Industrial	500	5.0	5.7	5.0
Local	7,500	4.0	7.5	7.1
Network	15,000	7.0	6.8	6.5

Every year, an investment program is developed according to the network conditions and needs. Good roads may not need any preventive maintenance, fair roads with an acceptable level of services are candidates for surface treatment and poor roads are divided in to roads with need of rehabilitation and reconstruction. To identify future needs and maintain acceptable levels of service five year programs are developed as well.

According to the measures of performance evaluating the network condition, 78% of network is above minimum acceptable level of service and 22% of network is below the level of service targeted.

Based on this analysis, the following graphic shows the budget allocation for local and major roads, been the priority major roads of the network.

Figure 3 Budget Allocation Between Major and Local Roads



CHALLENGES

Limited Rehabilitation Options Due to Urban Section

The treatment options available for the rehabilitation of streets in the urban environments are limited owing to various factors such as presence of curb and gutter, presence of buried utilities, traffic disruptions, access restriction to the businesses adjacent to the roads being rehabilitated to name a few.

Majority of the urban streets assessed for rehabilitation are observed to be structurally inadequate to support the design traffic. Some of these streets were constructed to lower standards (such as present day Arterial Street could have been a Collector Street at the time of initial construction or present day Collector Street could have been designed and constructed as a Local Street) or were not part of the transit corridor initially or are being subjected to higher traffic volumes than they were initially constructed for.

Pavement strength testing completed on Arterial and Collector roadway segments indicate strengthening requirements. In the event that the determined strengthening requirements are less than 50 mm of asphalt overlay, they can be achieved by mill and inlay of the existing pavements to varying depths. However, for some of the roadway segments where the strengthening requirements are greater than 50 mm, rehabilitation treatments including mill and inlay will not be able to provide adequate strengthening required for the design traffic over the design life of the pavement. As the majority (if not all) of urban streets are constrained by curb and gutter, strengthening of the roadway segments by placement of an asphalt overlay is not feasible as it would require the reconstruction of curb and gutters and sidewalks and tie-ins to the driveways or accesses to various businesses. In some extreme cases, the only option to achieve structurally adequate pavement structure would require reconstruction of the pavement. In many cases, this is not feasible considering the shallow depth of the buried utilities and the potential of unsuitable / contaminated soils underneath the pavement structure, which will complicate the problem if pavement reconstruction was to be undertaken. Other treatments such as Full Depth Reclamation (FDR) including stabilization, Cold-In-Place Recycling (CIR) are also sometimes not feasible owing to the thickness (of the asphalt pavement layer and granular materials) and quality of the existing pavement layers.

Maintaining Commercial and Residential Access

The construction of roadway rehabilitation treatments result in traffic closures and traffic detours for the duration of construction. Any work on the urban streets impacts access to the adjacent businesses and the residents. Therefore, the authorities tend to select the rehabilitation treatment options that result in minimal disruption to the traffic and discomfort to the general public wherever possible.

While the minor rehabilitation treatment options such as mill and inlay or placement of an asphalt overlay are relatively simple to construct and cause minimal traffic disruptions, they do not always provide the optimal solutions for pavement rehabilitation. Major rehabilitation treatment options such as FDR / CIR / reconstruction take long time to construct, resulting in severe traffic disruptions. Although the authorities can take some steps to minimize the impact of construction by staging construction activities or by completing some activities at off-peak hours or at night time, it is not always feasible. The construction limits access to the business on the side of the road (where businesses are present adjacent the road) directly impacting the businesses and their incomes. Even for the roads where there are no businesses adjacent to the road, construction activities result in restricting access to the nearby local streets, requiring detours and alternate routes for the impacted local residents.

Majority of the arterial and collector streets are on the Transit Route Network and the construction on these roads result in disruption / detour of the transit buses, thereby impacting the transit users.

Transit Bus Loading

Majority of the jurisdictions now have articulated buses in addition to the conventional buses in their fleet. Based on the survey completed with some agencies, majority of the bigger Cities indicated that the 60’ long articulated buses comprise approximately 10% of their total fleets. During peak travel periods, transit buses often accept as many passengers as they physically can (way above and beyond the maximum specified), resulting in higher axle loadings than those specified by the agencies.

To simplify understanding of the overloading issue, a comparison of the Equivalent Single Axle Loads (ESALs) for transit buses with other vehicles is presented in Table below.

Table 2 Equivalent Loading based on Comparative Equivalent Single Axle Loadings (ESALs)

Vehicle Type	Equivalent ESALs			
	Empty	50% Full Passengers	100% Full Passengers	130% Full Passengers
Passenger Car	0.0004	-	-	-
40' Transit Bus	1.27	1.80	2.67	3.29
60' Articulated Bus	2.53	3.63	5.11	6.17

Review of the data summarized in Table 1 indicate that 100% fully loaded and 130% fully loaded transit buses will cause equivalent damage as is caused by 6,700 and 8,225 passenger cars respectively. Similarly, damage caused by fully loaded and 130% overloaded articulated buses will be equivalent to the damage caused by 12,775 and 15,425 passenger cars.

The data summarized above indicates that one transit bus causes damage equivalent to the damage caused by thousands of passenger cars. The start and stop movements at the bus stops results in higher stresses on the pavements and is evidenced by the pavement in poor condition at the bus stops and the curb lanes along the transit routes for the majority of the areas.

Instability Rutting at Intersections and Bus Stops

Rutting is defined as the longitudinal permanent deformation or plastic movement of the asphalt pavement under the repeated loadings in the wheel-paths and is usually caused by the densification and shearing of different pavement layers. It is visually identified by the depression in the pavement surface along the wheel-paths.

Instability rutting is a result of inadequate HMA mix design rather than inadequate pavement structure. This type of rutting is caused by the shear deformation rather than densification and is visually recognized by the humps formed on the sides of the ruts as shown in the photographs below.

Photo 1: Instability rutting at the approaches to an intersection

Photo 2: Instability rutting caused by the Transit buses at approaches to a Bus Stop

The instability rutting is typically more evident in the slow trafficked areas of the pavements which represent a variance in the loading conditions applied to the pavements such as braking, accelerating, slow moving, turning and standing. Some material properties such as high pavement temperatures, rounded aggregates, too much asphalt binder or filler material and too low or too high air voids in the asphalt mix could also contribute to the instability rutting.

In addition to increase in the traffic volumes on various City of Calgary streets, number of transit buses and heavier commercial vehicles have seen significant increase in the past few decades. This increase in the number and loadings, combined with slow moving, braking, accelerating and turning movements at the intersections result in very high stresses in the pavement and cause the pavement to rut. Similarly, channeled traffic and braking, stopping and accelerating action at the same location at the bus stops by the transit buses also cause the pavements to rut at the these locations.

Moreover, some of the City of Calgary streets constructed few decades ago are full depth pavement structures and the asphalt pavement was constructed directly over clay subgrades. Although, the asphalt pavement layers are quite thick along the arterial streets and industrial streets, the presence of thicker asphalt structure make it more prone to rutting.

Underground Utilities

A variety of utilities like water lines, sewer lines, hydro cables, gas lines, phone lines, fiber optic communication lines etc. run under the streets. The presence of these buried underground utilities and their depth and location also limit the options available for the rehabilitation of the pavement.

Pavements in poor condition and in need of major rehabilitation intervention require detailed pavement evaluation and assessment including geotechnical investigations such as drilling of boreholes to assess the granular pavement layers, depth of water table and the type of the subgrade soils. The planned pavement evaluations are significantly impacted by the presence of underground utilities. At locations around Commercial Districts and Malls, there are a number of underground utilities below the pavement, making it almost impossible to complete intrusive investigations such as geotechnical borehole drilling. Sometimes, there is a discrepancy in the locations of the buried utilities on the as-built drawings and they are not correctly identified on these drawings. Considering the severe impact that a contact with one of these utilities can have during the assessment, it is not possible to complete the required investigations at the desired locations and alternative options such as selecting less appropriate locations with enough utility clearance and use of other methodologies such as drilling with Hydro Vacuum have to be employed.

For the pavements in poor condition and in need of reconstruction, the presence of underground utilities that are in good condition and do not need to be replaced, limit the depth of excavation for the construction of the pavement. If enough depth is not available, the only alternative available is either to construct a pavement structure with a shorter service life or raise the elevation of the pavement surface. The rise in the elevation of the pavement surface will need reconstruction of adjacent curb and gutters, sidewalks, access ramps and driveways and becomes expensive. This will also extend the construction duration and increase the inconvenience to the public.

Future planned upgrade of the underground utilities such as storm / sanitary sewer lines under the pavement could also impact the treatment options available for the rehabilitation of the pavements.

Utility Cuts

Numerous utility cuts are constructed in the pavements every year either to repair/upgrade an underground utility or to provide new connections to the businesses / residences adjacent to the roadway segment. These utility cuts adversely impact the performance of the pavements. While construction of some of the utility cuts could be mitigated by better planning and coordination of the City departments to undertake pavement rehabilitation in conjunction with upgrading of the underground utilities, it is not possible to completely avoid them.
While the utility cuts associated with new developments along the road cannot be predicted and are usually relatively small, sometimes large utility cuts are constructed within a few years following the rehabilitation of the roadway to upgrade or install a new utility under the pavement. These large utility cuts could be constructed by one of the City departments or other service providers such as Hydro, Gas, Cable or Telephone companies. In majority of the cases, these utility cuts severely impact the service life of the road and could be avoided by better coordination between the City departments and the utility providers.

In an effort to minimize such occurrences and to recover some of the costs associated with earlier than expected rehabilitation interventions necessitated by the utility cuts, the City undertook a study to analyze the impact of utility cuts on the pavement performance and have implemented charging of Pavement Degradation Fees on the parties responsible for the utility cuts.

Furthermore, the City has developed an electronic coordination map known as eMaps to coordinate all projects within the Roads right of way. The successfully implemented application has resulted in enhanced collaboration between several internal and external stakeholders reducing the number of utility cuts immediately after pavement rehabilitation.

Use of Reclaimed Materials (RAP and RAS)

With the depleting natural resources, there is a mandate from the owner agencies these days to increase the recycle / reuse of the materials and use products and technologies that are more environment friendly. The asphalt paving industry has had great success with recycling asphalt pavements and majority of the asphalt pavements are recycled these days and incorporated back into the pavements. In addition to the Recycled Asphalt Pavement (RAP), there has been a bigger push by the industry to incorporate Recycle Asphalt Shingles (RAS) into the Hot Mix Asphalt (HMA).

The current specifications of the City of Calgary allow for addition of up to 20% binder contribution as a percent of total binder content in the HMA. The research completed to date has indicated that the incorporation of RAP into the HMA doesn't impact its performance and that more care and attention is required in the management and characterization of the RAP stockpiles. The contracting industry is also pushing for the use of RAS into the HMA in dosage rates ranging from 2 – 5%.

The majority of the HMA mix design submitted by the contractors to the City currently include RAP and RAS. It has been observed that some of the recently constructed roadway segments in the City of Calgary appear to be relatively older for their age or under-asphalted. Furthermore, roads paved within 2 years have started to exhibit premature cracking. This phenomenon has also been reported by some other agencies as well.

As the asphalt cement in the RAS is highly oxidized (with typical penetration values of less than 20 dmm), the contribution of the asphalt binder from RAS to the HMA could not be ascertained. The asphalt mix designs are completed based on assumed binder contribution of 100% into the HMA, resulting in under-asphalting of the HMA.

As the current mandate of the agencies is to maximize the recycling and reuse of the construction materials, any effort to curb / lower the RAP/RAS use is opposed by the industry and is seen as being in contradiction of the mandate to promote green / environmental friendly sustainable policies.

Construction Variability

The roadway segments within the City were constructed over the period of time as per the specifications and the policies in effect at those times. While the construction methodologies, design standards and material specifications have changed over time, some of the roadway structures originally built more than 50 years ago are still in service, meaning that majority of these old roadways will not meet the current specifications.

Moreover, reconstruction and redevelopment activities in the past could have involved approaches and decisions that resulted in easier construction and cost savings at those times such as paving over the concrete foundations (falling within the footprint of the roadway being widened), paving over existing railway tracks, placing granular material over existing paved roads to adjust the roadway elevation, building roads on top of subgrade soils without placing any granular materials etc. As built records for roadway sections built long time ago are not available.

Sometimes, the variabilities discussed above could be limited to very small localized areas or various type of construction approaches could be present in a very short segment of the roadway. In most of the cases, the only way to identify these variabilities are by means of detailed investigations. The treatment options to address the construction variabilities could become tricky, expensive and very difficult to construct. For example, localized pavement failure caused by the presence of a sandwich structure will require the removal of the lower asphalt pavement (underneath the granular layer) and the granular layer and reconstruction of the pavement. Similarly, full depth pavement structures including asphalt pavement constructed over subgrade soils typically include thick ACP layers (ranging in thickness from 200 – 300 mm or more in some instances). Reconstruction of these roadway segments will include removal of the entire ACP layer and placement of new granular and ACP layers. As this will involve the exposing of the subgrade and some sub-excavation to allow for construction of new pavement structure, there is always a risk for detection of unknown issues during reconstruction.

Flooding Issues

The City of Calgary is located along the banks of the Bow River and there is always a potential for the river water to flow over its banks and flood the streets and the City as happened most recently in 2013. The City of Calgary witnessed the most severe flood in known history in 2013 which necessitated evacuation of about 100,000 residents and declaration of emergency for 15 days and caused several hundred millions of dollars in damage to the public and private infrastructure.

The flooding washed out many roadway sections and developed many sinkholes in the roadway. Multiple sinkholes were observed in several roadways and it was anticipated that the flood water was flowing in channels under the pavement surface. Some photographs showing the damage caused to the roadways infrastructure are shown below.

Photo 3: Undermined Sidewalk affected by 2013 Floods

Photo 4: Roadway segment damaged by 2013 Floods

While the timelines and extent of the recurrence of the floods cannot be predicted, events like this happening again cannot be ruled out either.

Although the evident distresses such as the sink holes at the surface and the damages caused to the sidewalks and other infrastructure have been repaired, the existence of unrepaired and undetected sink holes or the pavement channels formed during the 2013 flood event cannot be ruled out. The City undertook a detailed study to identify the potential voids underneath the pavement surface, it is a possibility that not all of the voids were identified and repaired at that time. While the evaluation was limited to the study of a few roadway segments severely affected by the floods, there is a possibility that some of the sinkholes or flow channels under the pavement surface went undetected and never appeared to the surface. There is a potential for those unidentified anomalies to collapse and surface during any future flood events.

CITY OF CALGARY INITIATIVES

Increased Use of Modified Binders and Alternative Materials

Generally, the instability rutting performance on the City's roadway network has improved significantly over the past 15 years. Likely the most positive influence on this improvement has been the use of modified binders and alternative Hot Mix Asphalt (HMA) materials. In a 2005 TAC paper [1], rutting performance of alternative materials was presented. The study looked at using the Asphalt Pavement Analyzer (APA) to assess the rutting potential of various mixes, including;

- Asphalt Rubber Gap Graded using 150/200 A asphalt cement;
- Superpave Nominal Maximum Size (NMS) Fine Graded with Sulphur Extended Asphalt Modifier (SEAM);
- Superpave Nominal Maximum Size (NMS) Fine Graded with PG 70-31 Polymer Modified Binder (PMA);
- Superpave Nominal Maximum Size (NMS) Fine Graded with PG 67-37 PMA and Reclaimed Asphalt Shingles (RAS);
- Stone Matrix Asphalt (SMA) with PG 70-31 PMA and Cellulose Fibre;
- Stone Matrix Asphalt (SMA) with PG 67-37 PMA and RAS.

The study included APA testing of both field cores and laboratory specimens. The testing program provided a foundation for successfully addressing instability rutting in most applications. Today, the City maintains the use of PMA binders for major roads and new construction. As well, the City continues an annual SMA program for high traffic, signalized intersection applications.

In terms of alternate materials and technologies the City has also been a leader in the trialing and adopting technologies such as Warm Mix Asphalt (WMA). A 2006 Canadian Technical Asphalt Association (CTAA) paper [2] described the City's initial full scale project to assess the potential benefits of WMA. This 2005 project represented the first full scale WMA installation in Canada. The results of this project formed the basis for ongoing use and assessment of WMA technology, which is still in use today.

More recently the City has addressed the significant challenge associated with transit bus traffic and particularly the pavement damage at bus stops. Currently, the norm is to provide and Portland Cement Concrete (PCC) pavements at these locations to address the significant stresses applied by transit buses, in particular articulating buses with significant loading.

Comprehensive Pavement Evaluations

In the early 2000's the City developed and adopted a tiered approach to the assessment and treatment selection for the rehabilitation of pavements. The approach included a Tier I assessment which was simply a "windshield survey" by City operations personnel for low volume residential roadways. The second level, Tier II was intended for medium volume roadways where the windshield survey would be supplemented by a desk study of available Pavement Management System (PMS) data, traffic data and any other available information on which to base treatment selection.

The third level of assessment, Tier III, represents a comprehensive pavement assessment of higher profile arterial roadways. These assessments include review of available information, traffic loading analysis, visual condition survey, Falling Weight Deflectometer (FWD) testing, Ground Penetrating Radar (GPR) or Road Radar™ Testing form pavement structure thickness, coring programs, and in some cases geotechnical assessment. These assessments have become the norm for the larger capital works rehabilitation projects and serve to provide a means where the most appropriate strategy, based on Life Cycle Cost Analysis (LCCA), is selected for a particular project. This approach has been valuable in optimizing the expenditures available and addressing many of the urban pavement challenges such as intersection rutting, traffic accommodation and business access.

The City maintains standing offers with qualified engineering consultants to undertake Tier III pavement assessments on an ongoing basis.

Construction Specification Development

In 2009 the City of Calgary commissioned Tetra Tech to undertake a comprehensive review of the City's standard specifications for road and other surface works construction. A process was developed that would incorporate input from a wide spectrum of stakeholders, and build consensus within the contracting and development industries as well as with City technical and administrative groups.

The initial step in this process was a half day project kick off meeting, bringing together a large number of people from across the various stakeholder groups. As part of this effort, working groups were tasked with discussing and reporting back on three fundamental questions. What do we want the specifications to achieve?

What level of responsibility (and risk) should be with the Contractor, Owner and Developer for quality? And, how do we balance initial cost with generational accountability?

The outcomes served to provide the review team with five guiding principles for the ultimate delivery of enhanced specifications, including;

1) Improved Clarity – As specifications evolve over time often revisions are made to address previous issues and new technologies. The revised specifications are presented in a clear and concise manner.

2) State-of-the-Industry Material and Construction Quality Standards – Provide the most recent recognized quality standards that will satisfy the expectations of Calgary taxpayers.

3) Clearly Defined Roles and Focusing the Responsibility for Quality on Contractors and Suppliers – Provide the means to enable Contractors and Suppliers to "take ownership" of their processes.

4) Delivering Cost-Effective and Sustainable Infrastructure - Consistent with the City's Plan-It and Triple Bottom Line direction, all aspects of project delivery must have the underlying principal to provide safe, reliable and sustainable infrastructure.

5) Fair and Equitable Resolution Process - Consistency, simplicity, risk management, and fair and equitable dispute resolution principals are essential to meeting industry objectives.

Over a period of 18 months an interactive process including, draft specification development, presentation to, and soliciting of input from, various industry stakeholder groups, developing consensus and incorporating input, was used to arrive at a solution that had "buy in" from all parties. This process was presented in a TAC paper in 2012 [3].

The specifications and requirements for pavement design, and materials selection, and materials and construction continue to provide a foundation on which surface works construction and rehabilitation projects are delivered in City.

Use of Recycled Materials

Agencies are increasingly mandated to encourage and incorporate green technologies into their everyday businesses. Diverting materials such as Recycled Asphalt Pavement (RAP) and Recycled Asphalt Shingles (RAS) from landfills and incorporating these materials in a responsible manner into asphalt mixes and/or pavement granular materials can be both environmentally and economically beneficial. The City strongly believes that responsible utilization of recycled materials does not mean that an agency should lower their expectations of pavement performance. In fact, the opposite can be the case, and that with the right quality control and engineering not only can pavement performance be maintained it may in some cases be enhanced.

To successfully incorporate RAP and RAS, an agency must have in place; firstly, specifications for the incorporation of RAP and RAS, and secondly, best practice guidelines or regulations for the handling, production/processing, stockpiling and characterization of RAP and RAS. One of the challenges that agencies face with incorporating reclaimed materials is that when the materials are reclaimed, there is seldom a contractual agreement between the agency and the contractor who has the reclaimed materials. As there is no contractual obligation between the agency and contractors, the agency's specifications may not be applicable.

The City has been proactive in assessing RAP and particularly RAS in a responsible manner. In a 20014 CTAA paper [4], the City in conjunction with industry publish and comprehensive assessment of RAS incorporation into HMA. This study, along with others, provided the basis for responsible use of recycled materials.

Enhanced QC/QA

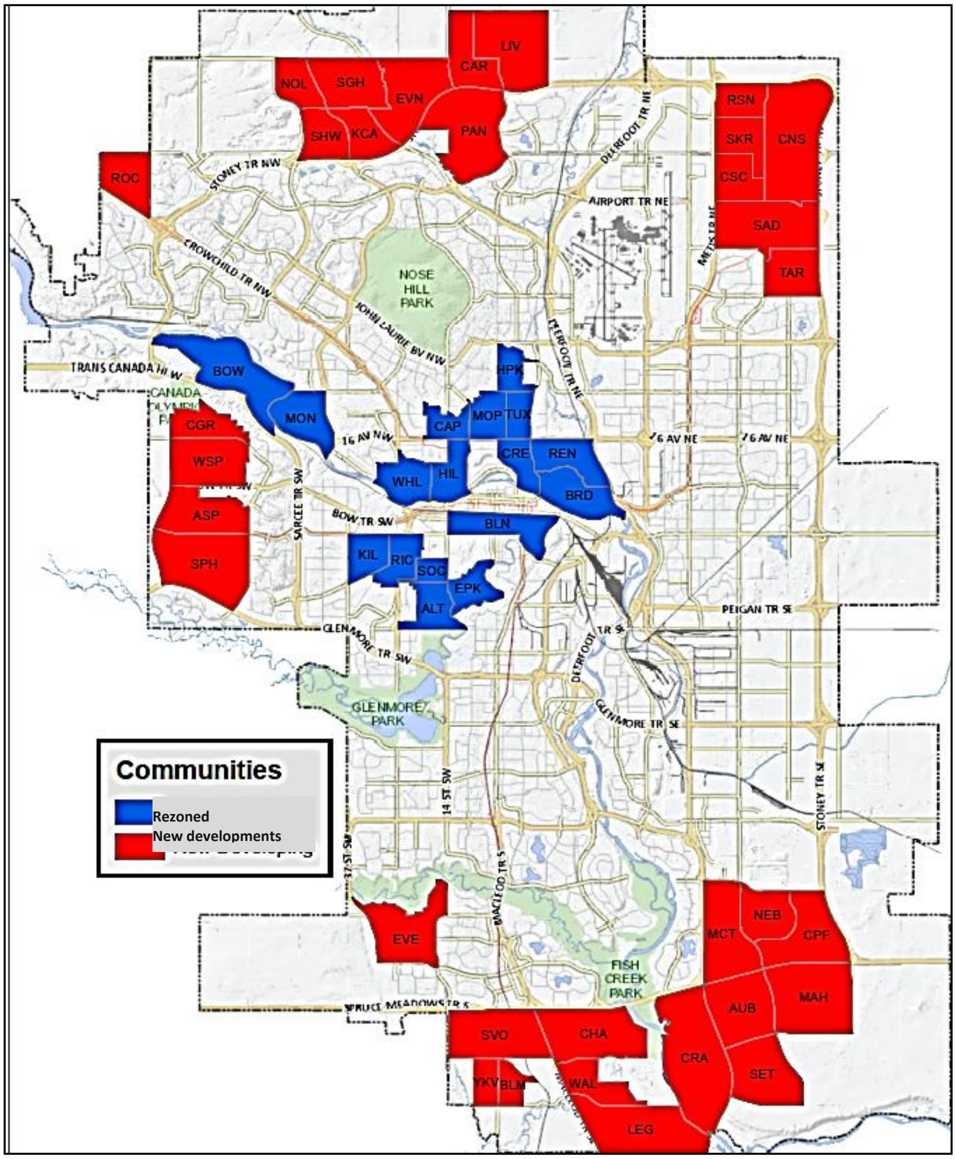
During the specification review process previously described, significant emphasis was focused on quality management, Quality Control (QC) and Quality Assurance (QA). This resulted in standalone sections for Materials, Execution, QC/QA, Acceptance Parameters, etc. In addition, a End Product Specification (EPS) based philosophy was adopted for all projects.

To address the issue of balancing the Quality Assurance (QA) effort with the size of the project a tiered system was developed including two Project Categories (one for larger Capital Works projects with statistical based acceptance and one for subdivision as well as smaller projects, QC based with QA audit).   Also adopted was appeal testing protocols for all parameters subject to payment adjustment. Payment adjustments were adopted for asphalt content, compaction, air voids, thickness, and in some cases smoothness. In some cases the adjustments were different for lower lift and upper lift to reflect the relative consequences of noncompliance.

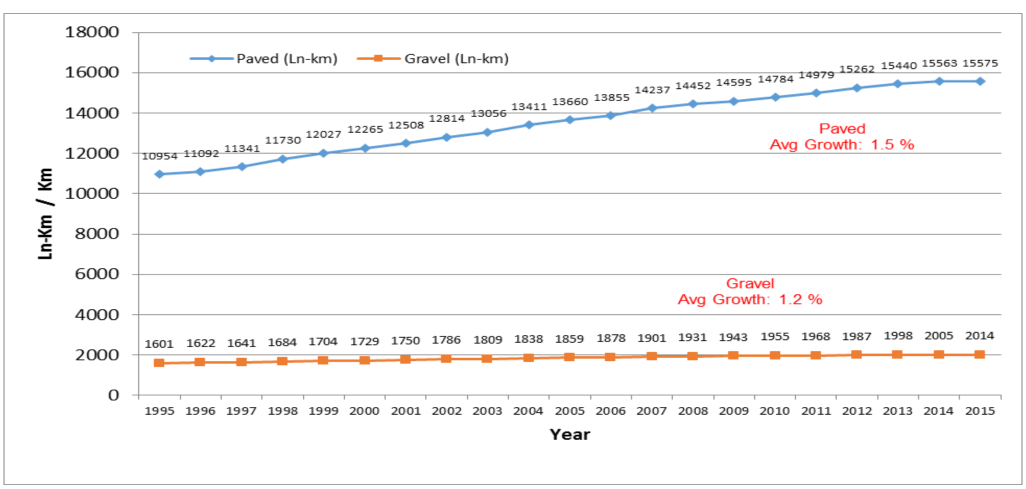
This initiative has assisted in “raising the bar” with respect to construction quality. Although challenges remain in terms of construction quality and maximizing the City’s investment in roadway construction, sound quality management principals are the key.

FUTURE CHALLENGES

Each year city Calgary’s road network is increasing because of new developments, redevelopment or because some communities are rezoned.



According to the City, paved and gravel roads are increasing 1.5% and 1.2%, respectively, on annual basis.



The City as well is working on many aspects of improving construction practices, pedestrian accommodation strategies, evaluation of alternative material for pavement, improvement of road construction specifications, technologies to fill data gaps and better coordination with costumers, builders, other municipalities or agencies

Research of new products, new technologies and materials continues to be a focus of the City such continual improvement of pavement infrastructure is achieved

CLOSURE

The authors trust that this paper has provided an insight to the challenges facing urban agencies with respect to pavement design, construction and rehabilitation of pavement infrastructure. Sharing of some of these challenges and the initiatives to meet these challenges was the primary objective of this paper.

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